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Economics of Retrofitting Big Rivers Electric Corporation's Lime-Based FGD (Flue Gas Desulfurization) System to Organic-Acid-Enhanced Limestone Operations

Peabody Process Systems, Inc., Norwalk, CT

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ECONOMICS OF RETROFITTING BIG RIVERS ELECTRIC CORPORATION'S LIME-BASED FGD SYSTEM TO ORGANIC-ACID-ENHANCED LIMESTONE OPERATIONS

by

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ABSTRACT

This report presents the results of a site-specific cost evaluation which was conducted to evaluate the costs associated with converting an existing lime FGD system to a limestone system enhanced by either adipic acid or DBA. The process data that was used as the bases for the cost estimates was collected in 1982-83 by Peabody Process Systems, Inc. (PPSI) at a pilot unit located at the R. D. Green Station of Big Rivers Electric Corporation (BREC). This report addresses the capital and operating costs of converting the R. D. Green Station which has two 240 MW FGD systems using dolomitic lime as a reagent. Results of the cost estimates indicate that an annual cost savings of $2.6 million could be achieved by converting the existing system to an adipic acid-enhanced limestone system, and an annual savings of $3.1 million could be achieved by converting to a DBA-enhanced system.

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SECTION 1

INTRODUCTION

In 1982-83, Peabody Process Systems, Inc. (PPSI) conducted pilot plant tests at the R. D. Green Station of Big Rivers Electric Corporation (BREC). PPSI's final report of the pilot testing included comparisons of the operating costs of a lime based, full-sized absorber, to a retrofit limestone system enhanced with dibasic acid (DBA) or adipic acid. The economics did not include the cost of new equipment required to make the conversion. This project was funded by the Environmental Protection Agency (EPA) in order to define the capital requirements necessary for the retrofit and thereby complete the economic comparison.

The existing R. D. Green Station has two 240 MW boilers that use an American Air Filter (AAF) Flue Gas Desulfurization (FGD) system employing a spray tower absorber and dolomitic lime as a reagent. Dolomitic lime enhances SO_2 removal efficiency through the accumulation of dissolved alkalinity, which allows a relatively low liquid-to-gas ratio (L/G) to be used for the system. Adipic acid and DBA enhance the performance of limestone scrubbing systems such that a mixture of limestone and DBA or adipic acid may be substituted for lime with minor changes to an existing FGD system.

This report addresses the site specific changes required for BREC to convert their existing lime FGD system to a limestone system enhanced by DBA or adipic acid, and the costs of making such a change. Results of this analysis, which was based upon site specific capital and raw material costs, indicated that an annual cost savings of $2.6 million could be achieved by converting the existing lime system to an adipic acid enhanced limestone system, and an annual savings of $3.1 million could be achieved by converting to a DBA enhanced system.

SECTION 2

BIG RIVERS, R. D. GREEN STATION - SYSTEM DESCRIPTION

The Big Rivers Electric Corporation's Green Units No. 1 and 2 each consists of a coal-fired steam generator with an electrostatic precipitator (ESP) followed by a wet sulfur dioxide (SO_2) absorber system. The steam generator is a Babcock and Wilcox balanced draft, pulverized-coal-fired, Carolina-type Radiant Boiler. The maximum continuous steam flow rate is 1,930,000 lb/hr[1] at 1975 psig superheater outlet pressure with 1,005° F main steam temperature. Two Ljungstrom Regenerative Tri-Sector air heaters transfer heat from the exit flue gas to the entering combustion air.

The flue gas exiting the air heaters is cleaned of particulate in an AAF ESP designed to remove 99.64 percent of the maximum expected load of 75,000 lb/hr of flyash. To achieve this, AAF installed a two-unit ESP: each unit has 48, 12-in. wide gas passages and collection plates 42 ft high. The gas passages have an effective depth of 55 ft, 5 in. (consisting of seven 7 ft 11 in. sections). Each ESP unit has two parallel electrical sections, which are seven fields deep.

AAF has also designed and manufactured the SO_2 absorption system. This system uses an aqueous slurry of dolomitic lime to react with the SO_2 and produce a calcium sulfite and sulfate slurry. The system consists of two spray tower reaction modules for each boiler, along with their associated pumps, valves, and controls. The system is designed to handle all of the flue gas from the steam generators and remove 90 percent of the SO_2. The absorbers are equipped with a bypass duct and damper arrangement which can be used to bypass flue gas in an emergency. Each module was designed to handle 60 percent of the rated full-load flue gas flow. Flue gas exiting the absorbers is reheated by heating ambient air in a steam-to-air heat exchanger and forcing the hot air into the duct connecting the spray towers and the stack with a separate reheat fan.

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(1) Environmental Protection Agency policy is to express all measurements in Agency documents in metric units. In this paper, however, English units are used to avoid lack of clarity. Conversion factors from English to metric units are given in Table 9 located at the end of this report.

The lime slurry is prepared in a lime slaker and pumped to the absorber recycle tank in response to decreases in pH. The pH is normally maintained at 7.0. The suspended solids are maintained at about 2.0 percent solids by the addition of a supernate from the thickeners and makeup water to the system. The waste slurry from the recycle tank, typically containing 2 to 3 percent solids, is fed to the four thickeners for primary dewatering. The supernate is returned to the scrubber system. The thickener underflow contains 20 percent solids and is fed to two of the three rotary drum vacuum filters for secondary dewatering. The vacuum filters discharge a 48 percent solids cake. This cake is blended with flyash and lime in a pugmill blender to produce a final product containing 60 to 65 percent solids. Over time, chemical reactions of the flyash and lime in the mixture produce a stable rock-like material suitable for a landfill. The key design parameters for the air quality control systems (AQCS) are summarized in Table 1.

Due to high water content in the filter cake, nearly all flyash produced by the two Green Units must be used to produce a final mixture with sufficient solids content (60 to 65 percent) for easy handling and transporting to the landfill. This solids content also ensures stable landfill material with relatively high strength and low permeability.

TABLE 1. AQCS DESIGN PARAMETERS BREC'S GREEN STATION UNIT NO. 2[a]

ESP	
Design collection efficiency	99.64%
Design pressure drop	0.75 in. W.G.
Design flow rate	1,000,000 acfm @ 300°F
Average face velocity	3.95 ft/sec
Treatment time	12.02 sec (6 fields)
Expected outlet dust loading	0.03103 gr/acf
Number of units	2
Number of gas passages	48
Number of fields	7
Plate height	42 ft
Plate width	7 ft, 11 in.
Plate spacing	12 in.
Total collection area (7 fields)	468,156 ft^2
Collection area with 6 fields (guarantee condition)	401,277 ft^2
Design SCA (6 fields)	400 ft^2/1,000 acfm
Design migration velocity (6 fields)	7.12 cm/sec
Guaranteed average power consumption (6 fields)	860 kW
FGD SYSTEM	
Design flow rate	1,000,000 acfm @ 300°F
Design SO_2 removal efficiency	90%
Number of modules	2
Tower diameter	34 ft

[a]Unit No. 1 is a mirror image of Unit No. 2 and has the same AQCS design parameters.

(continued)

TABLE 1. (Continued)

FGD SYSTEM (Continued)	
Spray zone height	26 ft
Number of spray levels	6
Sulfur in coal	4.0%
SO_2 to scrubbers	22,167 lb/hr
SO_2 absorbed	19,950 lb/hr
Design flow rate per module, saturated	446,200 acfm
Saturation temperature	128°F
Design velocity	8.2 ft/sec
Design recirculating slurry (per module)	21,275 gpm
Modified recirculating slurry (Module A)	14,900 gpm
Modified recirculating slurry (Module B)	16,500 gpm
Design total lime feed	19,133 lb/hr
Recycle tank volume	183,600 gal.
Number of thickeners	4
Thickener diameter	125 ft
Thickener volume	898,650 gal.
Design thickener capacity	37 ft^2/tpd dry solids
Design underflow suspended solids	30% (actual 20%)
Design underflow flow rate	160 gpm
Filter feedrate	291 gpm/filter
Design filter capacity	70 lb/hr/ft^2
Filter drum diameter	12 ft
Filter drum length	20 ft
Number of filters required per unit	2 + 1 spare
Cake moisture	48%
Flyash feed rate to pug mill	70,400 lb/hr
Lime feed rate to pug mill	4,000 lb/hr

(Continued)

TABLE 1. (Continued)

FGD SYSTEM (Continued)	
Lime stoichiometry	1.02 moles lime/mole SO_2 removed
Final composition flyash/ filter cake weight ratio	0.6/1
Lime in final mixture	2%
Final solids content, actual	60 - 65%
Final solids content, optimum	70 - 75%

SECTION 3

CONVERSION TO ORGANIC-ACID-ENHANCED OPERATIONS

PREDICTION OF FULL-SCALE SO_2 REMOVAL EFFICIENCIES WITH LIMESTONE/ORGANIC ACID

The BREC pilot plant test results could not be used to predict SO_2 removal efficiencies for the full-scale spray tower since wall effects reduced the spray zone mass transfer effectiveness for the pilot plant operations. An attempt was made to compare the existing BREC spray tower performance to the performance of the 10 MW Shawnee spray tower. Typically, larger diameter spray towers are more efficient than the 10 MW Shawnee spray tower; consequently, use of the 10 MW data for predicting full-scale performance should be conservative.

However, a direct comparison of the operation of the full-scale BREC spray tower to the Shawnee operations could not be made since much of the required process data (Mg^{++} concentration, pH, L/G, inlet SO_2 concentration, and temperature) were not available. For this reason, semi-empirical equations developed by Bechtel[1] for limestone scrubbing with adipic acid were used to estimate full-scale liquid pumping requirements for achieving 90 percent SO_2 removal as a function of inlet SO_2 concentration.

Adipic acid and liquid pumping requirements for the retrofit were calculated for several inlet SO_2 conditions. Increased L/G rates would be obtained by increasing the rpm of the existing recycle pumps to the capacity of the existing motors. DBA requirements would be the same as adipic acid when expressed as parts per million of equivalent adipic acid.

Table 2 shows the minimum L/G required to obtain 90 percent removal for different inlet SO_2 concentrations. As indicated, even at the highest sulfur coal, there is sufficient pumping capacity for meeting compliance when 3,000 ppm of adipic acid is used.

BASIS FOR RETROFIT EQUIPMENT DESIGN

The ultimate coal analysis typical of coal burned at BREC (Table 3) was used as a basis for performing combustion calculations. These combustion calculations assumed an excess air rate of 50 percent and a coal feed rate of 277,000 lb/hr which were consistent with operating conditions measured by Engineering Testing Services (ETS) in a series of tests to evaluate the performance of BREC's ESP in January 1982. Combustion calculation results shown in Table 4 were also consistent with values measured by ETS, and were thus used as the basis for performing material balance calculations to establish required equipment sizes.

TABLE 2. CALCULATED LIQUID TO GAS RATIOS REQUIRED TO OBTAIN 90 PERCENT REMOVAL[a]

Adipic Acid Concentration, ppm	L/G Ratios for Two Inlet SO_2 Concentrations, ppm[b]	
	2,500	4,000
0	103 gal./10^3 acfm	146 gal./10^3 acfm
1,000	88	125
2,000	51	72
3,000	29	42

[a]Calculated using semi-empirical model developed by Wang and Burbank (Reference 1).

[b]Available minimum liquid-to-gas ratio at BREC = 67.4 gal./10^3acfm.

TABLE 3. TYPICAL COAL ULTIMATE ANALYSIS BREC'S GREEN STATION UNIT NO. 2

	Percent by Weight	
	As Received	Dry Basis
Moisture	10.50	-
Carbon	58.86	65.77
Hydrogen	4.05	4.53
Nitrogen	1.23	1.37
Chlorine	0.05	0.06
Sulfur	3.53	3.94
Ash	14.44	16.13
Oxygen (diff.)	7.34	8.20
TOTAL	100.0	100.0

TABLE 4. COAL COMBUSTION CALCULATIONS

INPUT DATA

FUEL TYPE	COAL		
HEAT DUTY (MMBtu/hr)	4219.2	HIGHER HEATING VALUE (Btu/lb)	10548
TOTAL FLUE GAS W/O FLYASH (lb/hr)	5121000	EXCESS AIR SUPPLIED (%)	50.0
BOILER & AIR HEATER LEAKAGE (%)	0.0		
AMBIENT AIR TEMPERATURE (Deg F)	60	RELATIVE HUMIDITY (%)	0
PLANT ELEVATION NOT GIVEN --- ASSUMED SEA LEVEL		AMBIENT AIR PRESSURE (PSIA)	14.696
FLUE GAS TEMPERATURE (Deg F)	320	FLUE GAS PRESSURE (In. WC)	0.00
STANDARD GAS CONDITIONS: 70 Deg F & 14.696 PSIA			

RESULTS USING NORMALIZED ULTIMATE ANALYSIS OF FUEL

FUEL FIRING RATE (lb/hr)	400000	TOTAL FLUE GAS VOLUME (ACFM)	1642370
THEORETICAL COMBUSTION AIR-(ACFM)	698404		
ACTUAL COMBUSTION AIR (ACFM)	1047606	BOILER & AIR HEATER LEAKAGE (ACFM)	0
MOISTURE (lb water/lb dry gas)	0.0381	DRY FLUE GAS (lb/hr)	4932113
MOLECULAR WEIGHT (DRY/WET BASIS)	30.31 / 29.37	DENSITY OF FLUE GAS (lb/cu ft)	0.0520
SULFUR DIOXIDE CONC. (PPMD/PPMW)	2712 / 2549	HYDROGEN CHLORIDE CONC (PPMD/PPMW)	35 / 33
SULFUR DIOXIDE CONC. (lb/MM Btu)	6.693	REQUIRED SO2 REMOVAL EFF. per NSPS (%)	90.00
TOTAL ASH IN FUEL (lb/hr)	57760		

FUEL ANALYSIS

FUEL CONSTITUENTS	WEIGHT PERCENT INPUT	WEIGHT PERCENT NORMALIZED
CARBON	58.860	58.860
HYDROGEN	4.050	4.050
NITROGEN	1.230	1.230
CHLORINE	0.050	0.050
SULFUR	3.530	3.530
WATER	10.500	10.500
ASH	14.440	14.440
OXYGEN	7.340	7.340
TOTALS	100.000	100.000

TOTAL FLUE GAS ANALYSIS

FLUE GAS CONSTITUENTS	FLOW RATE lb/hr	FLOW RATE MOLS/hr	% (W/O FLYASH) WEIGHT	% (W/O FLYASH) VOLUME
SULFUR DIOXIDE	28240	441	0.6	0.3
NITROGEN	3669310	131047	71.6	75.7
OXYGEN	371078	11596	7.2	6.7
CARBON DIOXIDE	863280	19620	16.9	11.3
HYDROGEN CHLORIDE	206	6	0.0	0.0
WATER	187749	10431	3.7	6.0
FLYASH	0			
TOTALS	5119863	173141	100.0	100.0

RETROFIT EQUIPMENT REQUIRED

The existing lime system would be converted by utilizing as much existing equipment as possible. Only a ball mill and organic acid feed system will be added. The resulting simplified process flow diagram for the limestone preparation portion of the system is shown in Figure 1. No changes to the absorption portion of the system were required.

An existing equipment list of the BREC FGD system was prepared jointly by PPSI and BREC. A site visit was made by PPSI engineers to determine possible use of existing equipment in the limestone retrofit and to locate sites for new equipment construction.

Existing lime silos will be used for storage of coarse limestone; however, the lime slakers will not be operated. Three 50 TPH ball mills (one spare) will be housed in an electrically heated building near the existing silos. DBA or adipic acid storage and handling facilities will also be in the ball mill area. Conveyors have been priced to transport the crushed limestone from the storage silos to any of the three ball mill feeds. Supernate, tapped from a nearby 6 in. line, will be used to slurry the limestone, and the organic acid will also be added to the ball mill. A crane was priced for new ball addition to the ball mill.

Tanks, pumps, and agitators for the limestone/organic acid feed system were sized and priced based on maximum coal feed rate and maximum sulfur coal. It should be noted that costs for an electrical substation to provide power for the ball mills were not included since BREC felt that sufficient electrical capacity was available from existing equipment. If this substation were included, it would raise the capital costs by $52,000.

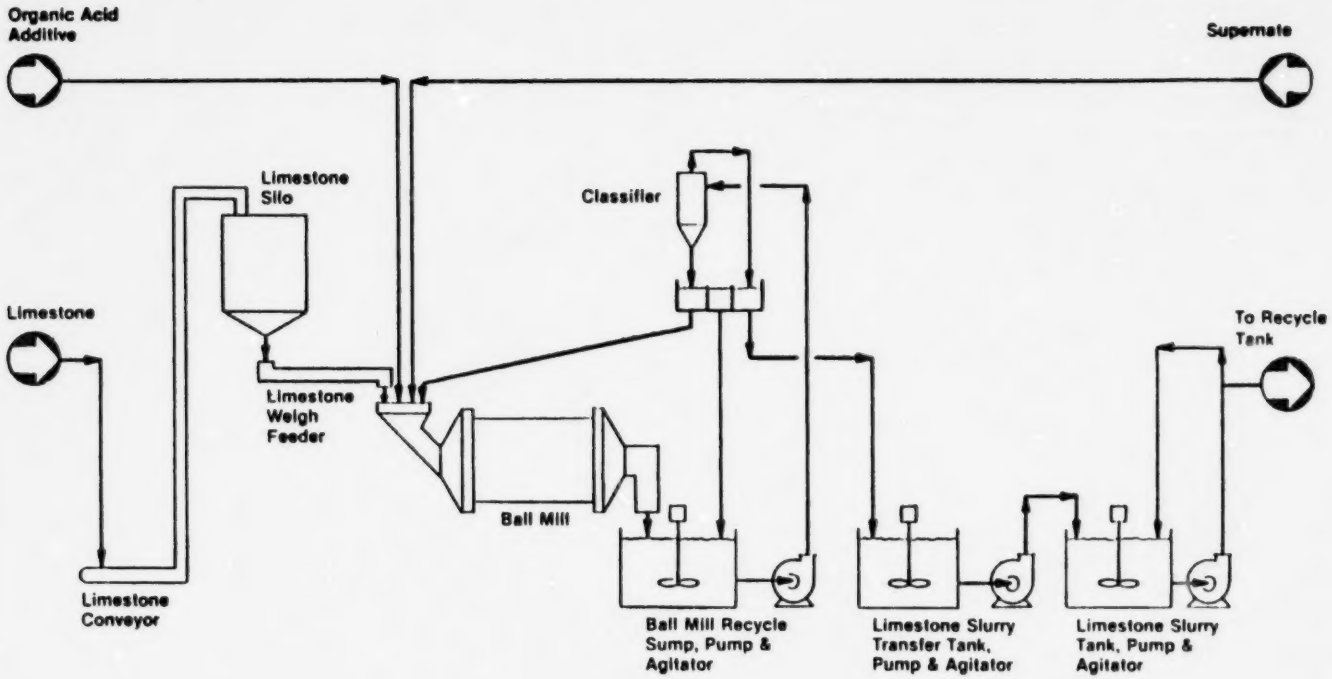

Figure 1. Limestone Preparation System

SECTION 4

COSTS

In order to provide cost comparisons of various full-scale process alternatives, a base case of BREC was calculated using the parameters in Table 5. The typical operating load of 75 percent was obtained using BREC projected load demands through 1995 (see Figure 2).

Potential process alternatives considered in this evaluation are:

- Limestone - with adipic acid addition.
- Limestone - with DBA addition.

Direct and indirect capital requirements for new equipment are summarized in Table 6. Capital requirements are based on equipment sizing for 100 percent load and maximum sulfur. The ball mills are very conservative since the limestone work index supplied by BREC for a typical quarry was 12. Other quarries were not surveyed, but finding a work index of 10 or lower should not be difficult.

Operating costs shown in Table 7 were calculated based on typical conditions using site specific raw material costs since an unfair advantage for limestone/organic acid would result at maximum boiler load and coal sulfur.

By using a fixed capital recovery factor of 20 percent, the annualized costs of a limestone/organic acid retrofit and the existing lime system were compared. The results shown in Table 8 indicate a yearly savings of $2,642,000 for limestone with adipic acid and $3,153,000 for limestone with DBA. These results would be different for other locations due primarily to variations in the cost differential between lime and limestone.

TABLE 5. PARAMETERS ASSUMED FOR BASE CASE CALCULATIONS
BREC'S GREEN STATION UNIT NO. 2

Plant Load	=	205 MW
Module Gas Flow	=	1,525,000 lb/hr/tower
	or	383,000 acfm/module
Inlet SO_2 Concentration	=	2,550 ppm wet
Lime Stoichiometry*	=	1.02
Lime Consumption	=	12 tons/hr
SO_2 Removal Required	=	90%
L/G (max.)	=	57
L/G (current)	=	41
CURRENT		
Recycle, Module A	=	14,900 gpm
Recycle, Module B	=	16,500 gpm
Operation	=	7,560 hr/yr
Cake Solids	=	42.0%

*Moles Ca per mole SO_2 absorbed.

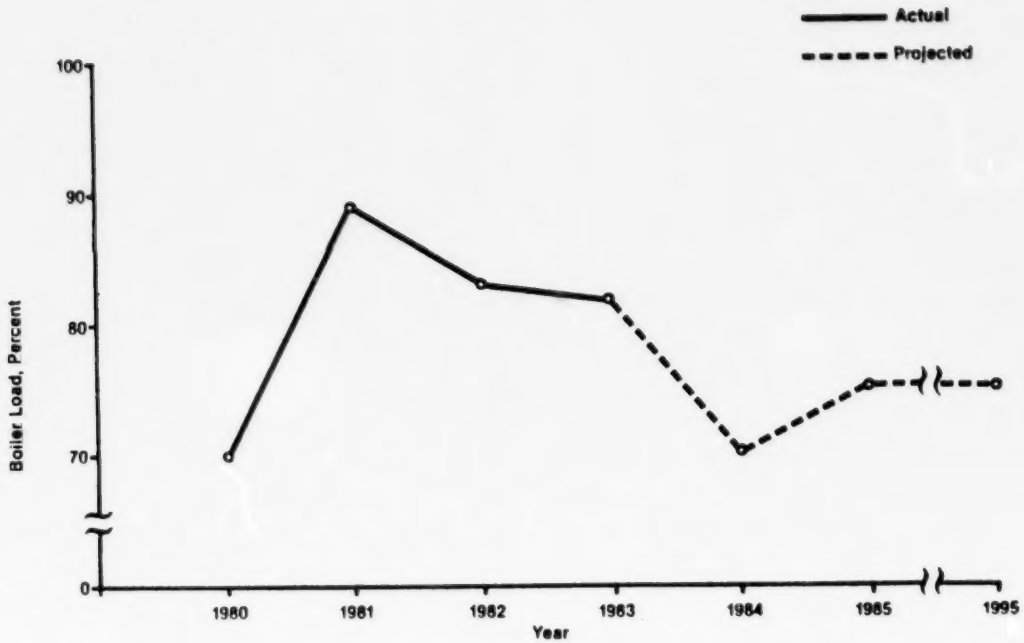

Figure 2. Green Station Operating Boiler Load; Actual and Projected

TABLE 6. COST ESTIMATE SUMMARY, BREC LIMESTONE/ORGANIC ACID RETROFIT
(1982 Cost Basis)

	Direct Investment ($1,000's)					
	Limestone/Adipic Acid			Limestone/DBA		
Description	Material	Labor	Total	Material	Labor	Total
Foundations, Site Prep.	50	50	100	50	50	100
Buildings	170	77	247	170	77	247
Structural Steel	94	56	150	94	56	150
Tank Heater				1	1	2
Process Tanks	4	2	6	24	8	32
Limestone Prep.	2,145	136	2,281	2,125	126	2,251
Pumps & Drives	18	4	22	18	4	22
Machinery	30	12	42	30	12	42
Insulation				6	6	12
Piping & Valves	105	65	170	105	65	170
Instrumentation	115	30	145	115	30	145
Electrical	173	108	281	173	108	281
Painting	1	4	5	1	4	5
Freight	25		25	25		25
Total Direct Costs	2,930	544	3,474	2,937	547	3,484
	Indirect Investment ($1,000's)					
Start-up Expenses		10	10		10	10
Field Expenses		20	20		20	20
Vendor Salary	100	20	120	100	20	120
Vendor Expenses	20		20	20		20
Vendor Overhead	100	20	120	100	20	120
Contingency	117	22	139	117	22	139
Vendor Profit @ 15%			585			587
Total Indirect Costs	337	92	1,014	337	92	1,016
Total Cost			4,488			4,500

TABLE 7. OPERATING COST SUMMARY - TYPICAL OPERATING CONDITIONS[a]
BREC LIMESTONE/ORGANIC ACID RETROFIT
(1982 Cost Basis)

	First Year Cost ($1,000's)		
	Lime	Limestone/Adipic	Limestone/DBA
Alkali			
Lime @ $60/ton	5,856		
Limestone @ $6.50/ton		1,222	1,222
Additive		931	418
Utilities			
Electricity @ $.01369/kWh	215	378	378
Total	6,071	2,531	2,018
Savings Compared to Lime System	-	3,540	4,053

[a]Typical Operating Conditions:
Firing Rate = 100 tons/hr per boiler
3.0% sulfur coal
Lime Stoichiometry = 1.02 mole CaO/mole SO_2 removed
Limestone Stochiometry = 1.05 mole $CaCO_3$/mole SO_2 removed

TABLE 8. BREC LIMESTONE/ORGANIC ACID RETROFIT PROJECTED FIRST YEAR COST DIFFERENTIAL FOR CONVERSION FROM LIME
(1982 Cost Basis)

	Limestone/Adipic	Limestone/DBA
New Investment Annual Charge @ 20% ($1,000's)	898	900
New Annual Operating Costs ($1,000's)	-3,540	-4,053
Total Annual Savings		
$1,000's	2,642	3,153
mills/kWh	0.927	1.106

TABLE 9. CONVERTING UNITS OF MEASURE

To Convert From	To	Multiply By
Btu	J	1,055
scfm (60°F)	Nm^3/hr (0°C)	1.61
cfm	m^3/hr	1.70
°F	°C	(°F-32)/1.8
ft	m	0.305
ft^2	m^2	0.929
ft^3	m^3	0.0283
gal.	l	3.79
gal./10^3 acfm	l/m^3	0.134
gr	g	0.065
in.	cm	2.54
in. w.g.	mm Hg	1.87
lb	g	454
psi	kPa	6.895
ton	metric ton	0.907

REFERENCES

1. Wang, S. C., and D. A. Burbank, "Adipic Acid-Enhanced Lime and Limestone Testing at the EPA Alkali Scrubbing Test Facility - Final Report, Volume I. Basic Report," EPA-600/7-82-010a, NTIS PB 82-230624, March 1982, pp. 198-201.

APPENDIX A

BIG RIVERS ELECTRIC COOPERATIVE
EQUIPMENT LIST AND DESCRIPTION OF
EXISTING EQUIPMENT FOR LIME BASED FGD SYSTEM

Quantities shown are for one (1) boiler unit.

Absorbers

Absorber [Two (2) existing] Open spray tower design approximately 34 ft. dia. x 69 ft. high straight sides. Includes: inlet quench section fabricated of carbon steel; absorption section fabricated of carbon steel; mist eliminator section fabricated of carbon steel; six (6) absorption stages; 3 top, 2 bottom pass Chevron type mist eliminator top fabricated of Ryton, and bottom fabricated of fiberglass; also includes integral recycle tank section fabricated of concrete, capacity 183,600 gallons; internal slurry spray piping fabricated of 316L SS, mist eliminator piping fabricated of 316L SS; 19 slurry spray nozzles in top three headers, 17 spray nozzles in bottom 3 headers, per level, 108 total, fabricated of Stellite and 122 mist eliminator wash nozzles fabricated of 316L SS.

Tanks

Reagent Storage Tank [One (1) existing] 113,100 gallon capacity. 24 ft. diameter by 28 ft. high. Carbon steel unlined. Open top.
Wash Tank [One (1) existing] 4,100 gallon capacity. 8 ft. diamater x 12 ft. high. Fabricated of carbon steel.
Secondary Recycle Tank [Two (2) existing] 196,000 gallon capacity. 34 ft. diamater x 29 ft. high. Type II concrete construction, flakelined. Agitator support level covered with grating.

Thickener ([Two (2) existing] 898,650 gallon capacity. 125 ft. diamater x 7'5" sidewalls. Includes carbon steel launders and side walls. Concrete base. Flakelined.
Supernate Tank [One (1) existing] 12,650 gallon capacity. 12 ft. diamater x 12.5 ft. high. Flat bottom, open top. Fabricated of carbon steel, flakelined.

Reagent Preparation System

Storage Silo [Two (2) existing] 4,045 ton capacity. 50 ft. diamater x 50 ft. high, carbon steel construction. Complete with top, required accessways vent filter and discharge hopper.
Silo Bin Activator [One (1) existing] Capacity 12 TPH complete with 7.5 HP drive. Manufactured by Vibranetics, Inc.
Silo Vent Filter [One (1) existing] Manufactured by American Air Filter.
Lime Feeder [Two (2) existing] capacity 12.5 TPH. Included 3 HP drive. Manufactured by Ft. Worth-Beeline.
Lime Slaker [Four (4) existing] Capacity 4 TPH each. Manufactured by Wallace & Tiernan, Series A-758.

Pumps

Reagent Slurry Pumps [One (1) existing plus one (1) spare, two (2) total] Size 6" x 6". Centrifugal type with V-Belt drive. 17 inch diameter impeller. Capacity 400 GPM at 90 ft. TDH. 25 BHP at 1,800 rpm. Rubber lined, vertically split. Manufactured by ASH, Model #B-6-5.
Absorber Recycle Pumps [One (1) existing per absorber plus one (1) common spare, three (3) total]. Size 20" x 20". Centrifugal type, V-Belt drive. 41 inch diameter impeller. Capacity 21,880 GPM and 105 ft. TDH. 800 BHP at 470 rpm pump speed. Rubber lined, vertically split. Sized for 23,000 GPM maximum at 800 rpm. Manufactured by Ash Model #GH-9-5.
Wash Pumps [One (1) existing per absorber, three (3) total] Size 2 x 8AN. Centrifugal type, V-Belt drive. Capacity 240 GPM at 220 ft. TDH. 25 BHP at

3,660 rpm. Rubber lined, vertically split. Manufactured by Ingersoll Rand, Model #2X8AN.

Waste Bleed Pump [One (1) existing plus one (1) spare per absorber, four (4) total] Size 6 x 6. Centrifugal type, V-Belt drive. 17 inch diameter impeller. Capacity 774 GPM at 70 ft. TDH. 30 BHP at 1,800 rpm. Rubber lined, vertically split. Manufactured by Ingersoll Rand.

Thickener Underflow Pump [One (1) existing plus one (1) spare per thickener, four (4) total] Size 3" x 3". Centrifugal type, V-Belt drive with manually adjustable variable speed drive mechanism, 12 inch diameter impeller. 15 BHP at 1m800 rpm. Rubber lined, vertically split. Manufactured by ASH.

Sump Pumps [Six (6) existing] Vertical type with 3 HP drive. Manufactured by Ingersoll Rand.

Agitators

Rubber covered shaft and impellers with flanged in-tank connections. Top mounted agitators have constant pitch, 4 bladed axial flow impellers, are provided with flow directing stabilizers.

Reagent Storage Tank Agitator [Two (2) existing] 20 BHP. Manufactured by Chemineer, Model #7-HTD-20.

Recycle Tank Agitators [One (1) existing each tank, 2 total] 25 BHP. Manufactured by Chemineer, Model #7-HTD-25.

Dewatering Equipment

Thickener Mechanism [Two (2) existing] Supplied with 5 HP drive motor. Designed for 125 ft. diameter thickener. Manufactured by Eimco/Envirotech.

Piping

Non Metallic Piping

FRP Pipe - Abrasive service - machine made vinylester resin pipe with abrasion resistant liner, bonded joint construction.

Installed uses:

Absorber Recycle Piping

Bleed Pump Piping

Spray Tower Quencher Piping

Screen Tank Piping

Ferrous Pipe

Carbon Steel Pipe (150# ANSI) - Carbon steel pipe and fittings, threaded construction 2" and smaller, butt welded construction 2-½" and larger.

Installed Uses:

Thickener Overflow Piping

Thickener Underflow Piping

Thickener Return Pump Piping

Recycle and Bleed Pump Piping

Traveling Screen Sprays

Lime Slaker Additive Piping

Fresh Water Supply Piping

Valves

Plug Valves - Slurry Service Manufactured by: Dezurik, Eccentric plug valves. Actuator Details: (Handwheel, lever, pneumatic, as required).

Ball Valves Manufactured by: Apollo, Model #82-100 Series.
Actuator Details: (Handwheel, lever, pneumatic, electric as required).

Butterfly Valves Manufactured by: Centerline, Actuator Details: (Handwheel, lever, pneumatic, electric as required).

Gate and Glober Valves Manufactured by: DeZurik, Actuator.

Instrumentation

Analog Logic System Manufactured by Fisher, Model #AC^2 1000.

Annunciator System Manufactured by Ronan, Model Series X-12.

Recorders Manufactured by Fisher, Model #RD221.

Controllers Manufactured by Fisher, Model #KM1308 + KD1131.

Indicators Manufactured by Fisher, Model #TL131.

Flow Instrumentation

Flow - Delta Pressure Manufactured by Fisher, Model #1151 DP.

Magflow meter Manufactured by Fisher/Porter, Model #50 PZ1000A.

Analyzers & Monitors

pH Analyzers Manufactured by Leeds & Northrup, Model 7073-11 & - 13

Nuclear Density Meters Manufactured by Texas Nuclear, Model #SGH.

Sulfur Dioxide Analyzers Manufactured by DuPont, Model #460

Transmitters

Level Transmitters Manufactured by Rober Shaw, Model #314B & 304A

Level Switches Manufactured by BLW, Model #Series 52

Pressure Transmitters Manufactured by Fisher, Model #1144

Differential Pressure Transmitters Manufactured by Fisher, Model #1151 DP

Electrical

Motors

Lime Slaker Motors ([Four (4) existing] 1/4 HP, 1750 rpm. Manufactured by Baldan.

Pump Motors

Reagent Slurry Feed Pumps [Two (2) existing] 20 HP, 3,600 rpm. 400 VAC

Absorber Recycle Pump Motor [Three (3) required] 800 HP, 1,200 rpm. 4,160 VAC Manufactured by Westinghouse, Model #HSW2.

Wash Pump Motor [Three (3) existing] 25 HP, 3,530 rpm. 460 VAC Manufactured by Westinghouse, Model #TBFC.

Waste Bleed Pump Motors [Four (4) existing] 30 HP, 1,770 rpm. 460 VAC Manufactured by Westinghouse, Model #TBFC.

Supernate Pump Motor [Two (2) existing].

Thickener Underflow Pump Motors [Four (4) existing] 15 HP, 1,755 rpm. 460 VAC.

Agitator Motors

Reagent Slurry Storage Tank Agitator Motor [Two (2) existing] 5 HP, 1,145 rpm. 460 VAC. Manufactured by Westinghouse, Model #TBFC.

Recycle Tank Agitator Motor [Two (2) existing] 25 HP, 825 rpm. 460 VAC. Manufactured by Westinghouse.

Additive Storage Tank Agitator Motor [Two (2) existing] 20 HP, 885 rpm. 460 VAC. Manufactured by Westinghouse, Model #TBFC.

APPENDIX B

BIG RIVERS ELECTRIC COOPERATIVE
EQUIPMENT LIST AND DESCRIPTION OF
NEW EQUIPMENT REQUIRED FOR
LIMESTONE/ORGANIC ACID RETROFIT

Unless otherwise indicated, weights are unit weights.

A. Foundations The work under this code will include all subgrade foundations, grade beams, slabs on grade, concrete walls, elevated slabs, and grouting stipulated as the work of this contract. This will include the foundations for the precipitator and its support steel, system ductwork, induced draft, booster and reheat fans, electrical, control, reagent preparation, and dewatering buildings and foundations for all associated equipment:

A200 Foundations

A220 Reagent Prep. Area 236 cubic yards concrete required

B. Architectural

B200 Designed Buildings

B230 Reagent Prep. Building [One (1) required] This building houses the ball mills, classifiers, transfer pumps and other equipment necessary for the grinding of limestone and also organic acid preparation and storage equipment. A switchgear room and control room are also provided in this building. The building is a metal sided structure, 60 ft. long, 65 ft. wide and 40 ft. high and will be lighted, heated, and ventilated with air-conditioning and a hung ceiling in the control room.

C. Structural Steel

C400 Reagent Preparation Area Structural Steel
C410 Light Steel (0-17 lbs. per ft.) 40 tons
C411 Medium Steel (18-35 lbs. per ft.) 25 tons
C412 Intermediate Steel (36 - 100 lbs. per ft.) 5 tons
C415 Grating - 200 sq. ft.
C416 Handrail - 150 Linear ft.
C417 Kickplate - 150 Linear ft.
C420 Ladders - 40 Linear ft.
C421 Cages for Ladders - 35 Linear t.

G. Tanks

G010 Reagent Transfer Tank [One (1) required] 5,000 gallon capacity. 10 ft. diameter x 10 ft. high. Carbon steel construction, unlined, open top.
G020 DBA Storage Tank [One (1) required] 12 ft. diameter x 24 ft. high. 20,000 gallon tank, manufactured with 304SS.

I. Reagent Preparation System

I250 Ball Mill Feed Conveyors [One (1) required] Capacity 100 TPH. 300 ft. long belt. Includes electronic load cell type belt scales, drive.
I300 Grinding System
I320 Ball Mill Weigh Feeder with Motor [Three (3) required plus 0 spares] Capacity 25 TPH. Includes drag conveyor. Gravimetric type. Includes 2 HP drive.
I340 Ball Mill System
I341 Ball Mill [Two (2) required plus 1 spare] Grinding capacity 50 TPH. Complete with lube system and high lift pumps. 750 BHP.
I342 Mill Slurry Sump [Three (3) required] 3,000 gallon capacity. Carbon steel construction, unlined.

I343 Wet Cyclone Classifier Assembly [Two (2) required plus 1 spare] Sized to produce a limestone of 90 percent minus 325 mesh at the rate of 50 TPH (dry basis). Complete with manifold and assembly inlet and outlet launders and distribution boxes and chutes.

I344 Ball Charge for Grinding System [Three (3) required]

I350 Chutes for Grinding System [Three (3) required] From weigh feeder to mill and from mill to sump.

J. Pumps

J010 Mill Recycle Pumps [Two (2) required plus 4 spares] Size 6 x 4. Centrifugal type with V-Belt drive. Capacity 860 GPM at 64 ft. TDH. 36 BHP at 960 rpm. Rubber lined, vertically split.

J030 Reagent Feed Pumps [One (1) required plus 1 spare] Size 8 x 8. Centrifugal type. Capacity 1,140 GPM at 65 ft. TDH. 43 BHP at 800 rpm. Rubber lined, vertically split.

J150 Sump Pumps [One (1) required] Duplex type with 3 HP drive. Sludge system pumps.

L. Machinery

L260 Bridge Cranes and Motors

L261 Ball Mill Building Traveling Beam Hoist [One (1) required] 5 ton capacity, electric wire rope hoist with motorized trolley and motorized traveling beam.

M. Agitators

Rubber covered shaft and impellers with flanged in-tank connections. All metallic components in contact with slurries are Alloy 20.

M010 Reagent Transfer Tank Agitator [One (1) required] 3-½ BHP.

M080 Mill Recycle Sump Agitator [Three (3) required] Supplied with 5 HP drive.

T. Piping

T100 Lined Piping

T110 Rubber Lined Pipe - PPS Class A Specification: Carbon steel pipe with ¼" thick rubber lining; butt-welded and flanged or Victaulic coupling construction.

T111 Mill Recycle Piping

T200 Non-Metallic Piping

T210 FRP Pipe - Abrasion Service - PPS Class H Specification: Machine made vinylester resin pipe with abrasion resistant liner; bonded joint construction.

T211 Reagent Prep. Area Piping

T212 Reagent Distribution Loop

T219 Miscellaneous Slurry Drains

T220 FRP Pipe - Corrosion Service - PPS Class J Specification: Machine made vinylester resin pipe with corrosion resistant veil liner; bonded joint construction.

T222 Reagent Prep. Area Supernate Piping

T331 Instrument Air Piping

T400 Ferrous Piping

T410 Carbon Steel Pipe (150# ANSI) - PPS Class D
Specification: Carbon steel pipe and fittings, threaded construction 2" and smaller; butt-welded construction 2-½" and larger.

T414 Seal Water Piping

T500 Specialties & Miscellaneous

T530 Strainers

T531 Pipeline Strainers - "Y" Type - PPS Specialty Items SP2, SP8, SP28, and SP29: Carbon steel "Y" type strainer, 316 S.S. screen.
Application: Seal water system; at steam traps; compressed air.

T532 Start-up Strainers - Basket type - PPS Specialty Item SP13: Conical perforated basket strainer, 316 S.S.
Application: at all rubber lined pumps.

T560 Flushing Spacers - Fabricated from polyvinyl chloride (PVC) plate, 1½" thick. Application: at all level transmitters in slurry tank service.

T600 Valves - Types of valves, service applications and quantities are tabulated below.

T620 Plug Valves

T621 Plug Valves - Slurry Service - PPS Valve Spec. V1 and V2: Abrasion resistant eccentric plug type with manual or pneumatic operators. Application: Slurry pump and equipment isolation; all slurry drains.

T630 Ball Valves

T632 Ball Valves - General Service - PPS Valve Spec. V9 and V97: Forged bronze ball valves, bronze trim. Application: seal water piping; compressed air piping.

T640 Butterfly Valves

T680 Pinch and Diaphragm Valves

T681 Pinch Valves - PPS Valve Spec. V57: Enclosed body type with positive opening sleeve, pneumatically operated. Application: Reagent or flyash slurry throttling to absorbers; slurry feed throttling to reagent storage tanks.

T700 Pipe Expansion Joints

T710 Pipe Expansion Joints - Slurry Service - PPS Specialty Item SP12: Double filled-arch type, reinforced rubber tube, integral flanges. Application: All slurry pump suction and discharge piping.

T720 Pipe Expansion Joints - General Service - PPS Specialty Items SP5 and SP32: Single bellows type, rubber body, unfilled arches. Application: Non-abrasive service; water service pumps.

T800 Pipe Supports

T810 Fabricated Steel Supports - Engineered and prefabricated structural steel supports, stanchions, T-posts, and all other support components fabricated from structural members. Application: Type I and Type II piping systems.

U. Instrumentation

U100 Control Panel

U130 Reagent Prep. System Control Panel - Approximate dimensions: 12 ft. long x 7 ft. high x 30 inches deep.

U200 Digital Control System

U230 Reagent Prep. Control System Digital Logic System The reagent Prep. Control Digital System shall consist of 1 programmable controllers, complete with CPU, power supply and input/output modules as required.

U270 Logic System Accessories

The following accessories shall be furnished for the digital logic system:

One Manual Programmer Panel
One CRT Programmer Panel With Tape Loader
One Tape Loader
Tapes for Loader
One Telephone Interface
One Printer

U300 Control Panel Display

U310 System Status Annunciators

U313 Reagent Prep. System Annunciator Alarm annunciator complete with power supply, horn, and test acknowledge and reset pushbuttons.

U350 Recorders [Two (2) required]

U360 Controllers [Three (3) required]

U400 Flow Instrumentation

U420 Magmeter Flowmeters [One (1) required]

U440 Rotameters - Quantity 2¼" or ½" bronze ball sight type.

U734 Pressure Gauge with Seal [One (1) required]

U735 Pressure Switch [One (1) required]

U860 Field Instrument Cabinets

U862 Reagent Preparation [One (1) required]

V. Electrical

V100 Power Distribution Equipment - The electrical equipment to be furnished and the work to be performed provides for an electrical responsibility that consists of the designing and delivery, testing, and placing in service all the electrical and control equipment necessary for the proper and safe operation of this installation.

V110 Middle Voltage

V111 H.V. Switchgear [One (1) required] Lineup of 4.16 KV indoor metal-clad switchgear will be provided and located at the supply. This lineup will supply power to common and unit equipment and will consist of:

One (1) 750 - KVA distribution transformers.

V120 Low Voltage

V124 480 Volt Motor Control Center [One (1) required] Motor Control Centers will be provided with 600 ampere main horizontal bus. The motor control centers provided will individualize and restrict usage to a specific area. Drawout combination starter/circuit breakers will power motors rated 460-Volts. Feeder breakers will distribute power to Process Equipment requiring 460-Volt or less power.

V130 Power Distribution Panels - The distribution equipment shall be so designed to provide the following voltages at the site:

(a) 480/277 volt panel Three Phase, Four Wire

(b) 240/120 volt panel Single Phase

(c) 208/120 volt panel Three Phase, Four Wire

V131 480/277 Volt-Power Distribution Panels [One (1) required] 480/277 Volt, three phase, four wire distribution panels will be furnished.

V132 240/120 V-Power Distribution Panel [One (1) required] 240/120 Volt singles phase, three wire distribution panel will be furnished.

V133 208/120 Volt-Power Distribution Panels [One (1) required] 120Y/208 Volt three phase, four-wire distribution panels will be furnished.

V300 Conduit System

V310 H.V. Conduit System & Description

V320 L.V. Power Cable Conduit L.V. Conduit System shall be provided.

V330 Control Cable Conduit Required control conduit System shall be provided properly located and installed in specific areas and complemented by the Control Cable Control Cable Tray System.

V340 Instrument Cable Conduit Instrumentation Conduit System shall be provided properly located and installed in specific areas.

V400 Wire Cable & Bus Duct

V410 M.V. Power Cable Power cable system for 600-Volt or less Process System Services shall be 90 degree C. triplexed propylene rubber insulation cable with neoprene jacket. These cables shall be stranded copper wire.

V420 L.V. Power Cable Power cable system for 600-Volt or less Process System Services shall be 90 degrees C. triplexed propylene rubber insulation cable with neoprene jacket. These cables shall be stranded copper wire 1,000 volt.

V430 Control Cable Control cable system for Process System Services shall be 90+o- cross-linked polyethylene insulation cable with hypalon jacket.

V440 Instrument Cable Instrumentation and Thermocouple Cable System for Process Services shall be 90 degrees C. shielded twisted pairs with individual drain wires and an overall drain wire.

V500 Lighting Lighting installation within the battery limits shall be provided, including lighting panelboards, fixtures, lamps, and switches that will furnish adequate 24-hour lighting levels for operation, maintenance, safety, and safe movement of personnel.

V700 Above Grade Grounding Grounding system provided for tie-in to existing system.

VI000 Motors

VI341 Ball Mill Motors [Three (3) required] 800 HP. 1,200 rpm. 4,160 VAC

VJ000 Pump Motors

VJ010 Mill Recycle Pump Motors [Six (6) required] 40 HP, 1,800 rpm. 480 VAC

X. PAINTING

X100 Field Touch-up

X200 Final Painting

X210 Metal Surfaces

X220 Foot Traffic Surfaces

X240 Uninsulated Piping